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Identifying electricity-saving potential in rural China: Empirical evidence from a household survey

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HIGHLIGHTS

- Electricity saving potential of rural households in China is examined.
- Unique survey data from the CRECS in collaboration with the CGSS are used.
- A stochastic frontier model is applied.
- Information feedback and social-demographic characteristics matter.
- Electricity price or energy efficiency tier rating does not matter.

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ABSTRACT

In recent years, there has been a fast-growing body of literature examining energy-saving potential in relation to electricity. However, empirical studies focusing on non-Western nations are limited. To fill this gap, this study intends to examine the electricity-saving potential of rural households in China using a unique data set from the China Residential Electricity Consumption Survey (CRECS) in collaboration with the China General Social Survey (CGSS), conducted nationwide at the household level in rural China. We use a stochastic frontier model, which allows us to decompose residential electricity consumption into the minimum necessary amount of consumption based on physical characteristics (e.g. house size, house age, number of televisions or refrigerators) and estimate the consumption slack (i.e. the amount of electricity consumption that could be saved), which depends on various factors. We find that rural households in China are generally efficient in electricity saving and the saving potential is affected by (fast) information feedback and social-demographic characteristics, instead of by the (averaged) electricity price, or energy efficiency labelling signals. In addition, we find no evidence of regional heterogeneity on electricity saving potential for rural households. Policy implications are derived.

1. Introduction

In 2014, China had more than 600 million people living in vast rural areas (World Bank, 2015). Due to rapid rural development, rural energy consumption has substantially increased in China, from 75.33 million tce (tons of coal equivalent) in 1992 to 158.65 million tce in 2012, with an annual growth of 7.7% (National Bureau of Statistics, 2014). Based on the population projection by the World Bank (2015), the total population of China will reach approximately 1.4 billion in 2030. Even if China can maintain stable urbanisation and reach an urbanisation rate of around 70% by that time, there will still be more than 400 million people living in rural areas. This means China faces a long-term challenge regarding energy consumption by the large population in rural areas. Combined continuing urbanisation, poverty reduction and energy structure transformation in wide rural China, the residential electricity demand would be expected to grow rapidly mainly resulted from more appliance ownerships (O'Neill et al., 2012; Auffhammer and Wolfram, 2014). For example, the ownership rate of colour television set in rural China increased from 4.7% in 1990 to 116.9% in 2012 dramatically. The ownership rates of washing machine and refrigerator also changed from 9.1% and 1.2% in 1990 to 67.2% and 67.3% in 2012, respectively (National Bureau of Statistics, 2015a). In an outlook of economic development and electricity demand in China, Hu et al. (2013) suggested that the residential electricity demand would reach 1332.2 TWh and

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2129.0 TWh in 2020 and 2030 according to a baseline scenario analysis. And it would grow to 3315.4 TWh and 4161.3 TWh in 2040 and 2050 by an input-output model.

In addition to the challenge of energy saving, residential electricity demand growth could make it difficult for China to meet its CO_2 emissions targets. China has made a commitment of achieving the peak of CO_2 emissions around 2030 or much earlier and increasing the share of non-fossil fuels in primary energy consumption to around 20% by 2030 (White House, 2014). Furthermore, China would also lower CO_2 emissions per unit of GDP by 60–65% from the 2005 level by 2030 (White House, 2015). Given that coal currently accounts for 78.2% of electricity generated (National Bureau of Statistics, 2015b), there would exist a conflict between electricity demand increase and emissions reduction strategies. Zhang et al. (2015) found that household energy consumption and its energy intensity are key driving factors to both indirect energy consumption and CO_2 emission. Thus, studies on rural household energy consumption, no matter whether they are aimed at improving the living conditions of rural people, reducing energy consumption, improving environmental quality, or promoting economic development, have practical implications. Although there are abundant studies on the above issues, special attention will be paid to households' energy-saving potential in rural China, particularly electricity-saving potential, which is as yet unknown.

Energy conservation and emission reduction are important issues in forming a long-term energy strategy. One strategy is to change households' energy consumption behaviour (Truelove and Parks, 2012; Yue et al., 2013). Energy-saving potential (for residential electricity consumption) has been found to be critical (Alfredsson, 2004; Carlsson-Kanyama et al., 2005; Benders et al., 2006; Vringer et al., 2007; Murata et al., 2008; Gardner and Stern, 2008; Dietz et al., 2009). For instance, using a questionnaire survey data from thirteen cities in China, Murata et al. (2008) estimated that a 28% reduction in electricity consumption by the year 2020 could be achieved through improving the efficiencies of end-use appliances. Gardner and Stern (2008) and Dietz et al. (2009) estimated that the energy consumption of U.S. households could be reduced by 20–30% by changing the selection and use of household and motor vehicle technologies.

Existing studies on residential electricity-saving behaviours are abundant,[1] and they provide vital information regarding the determinants of residential electricity-saving behaviour. However, there are few empirical studies addressing Chinese households' electricity-saving behaviour (Lu, 2006; Andrews-Speed, 2009; Ouyang and Hokao, 2009; Wang et al., 2011; Yue et al., 2013) and studies focusing on rural China are especially scant to the best of our knowledge.

To fill this gap, this study intends to examine the determinants of the electricity-saving potential of rural households in China using a unique data set from the China Residential Electricity Consumption Survey (CRECS) in collaboration with the China General Social Survey (CGSS) conducted nationwide at the household level in rural China. We use a stochastic frontier model, which allows us to decompose residential electricity consumption into the minimum necessary amount of consumption and estimate the amount of electricity consumption that could be saved.

This study differs from existing studies in two major respects. First, unlike the studies of Feng et al. (2010), Ouyang and Hokao (2009), Wang et al. (2011) and Yue et al. (2013), which targeted residents in a particular region in China (Hangzhou City, Liaoning Province, Beijing and Jiangsu Province respectively), this study focuses on rural households in China and uses the surveyed data covering 3404 rural households in 12 provinces.[2] Second, existing studies do not disentangle irreducible consumption (i.e. necessary consumption) and consumption slack (i.e. reducible consumption) from total residential electricity consumption; even though households may consume the same amount of electricity, the consumption slack or reducible consumption can vary depending on the household's electricity-using habits, social norms concerning energy saving, etc. Inspired by Yang et al. (2013) that energy saving potential of telecom operators in China is calculated by dividing total energy saving into technology part and management part, and by a recent study of Mizutani and Nakamura (2015), this study aims to identify the aforementioned two types of consumption and their driving forces using stochastic frontier methodology. The main result is that rural households in China are generally efficient in electricity saving with the average electricity efficiency score value of 93%. The electricity saving potential is affected by information feedback, instead of by the electricity price change, or energy efficiency labelling signals. Neither is there a regional heterogeneity effect. There are at least two important policy messages for policymakers. First, the transition of energy consumption structure is urgent since general electricity efficiency is high in rural China. Second, as a supplement of electricity tariff and China Energy Label System, the information feedback services need to be enhanced to discourage residential electricity use in rural China.

The rest of this paper is organised as follows. Section 2 presents a simple model of electricity demand. Section 3 discusses the stochastic frontier model, followed by the data sources introduced in Section 4. Section 5 presents the empirical results. The final section concludes with policy implications.

2. A simple model of the electricity demand frontier

Following Mizutani and Nakamura (2015), total electricity demand can be decomposed into two components, the irreducible amount regardless of price and the reducible amount due to a household's wasteful use of electricity. That is, the total amount of electricity demand q can be written as,

$$q = n(H|p_l < p < p_u) + s \qquad (1)$$

where the total amount of electricity consumption (q) is the sum of the minimum necessary amount of electricity of a household n that is determined by the physical aspects of a household H (e.g. number of bedrooms, floor size, appliances, or family members) under the condition that price p is within the acceptable range for households ($p_l < p < p_u$), and the reducible amount s, the so-called "consumption slack". Assuming that the household maintains its current lifestyle, $n(H)$ can be interpreted as a fixed cost as the

[1] Existing studies on residential electricity-saving behaviours can generally be classified in relation to two aspects: internal incentives and external incentives. Internal incentives predominantly include demographic variables, such as the householder's age, gender, level of education and income (Becker et al., 1981; Al-Ghandoor, 2009; Zografakis et al., 2010; Gatersleben et al., 2002), attitude variables, such as the household's attitudes towards certain energy issues (i.e. energy scarcity) and pro-environmental awareness (Nord Lund and Garvill 2003; Abrahamse and Steg, 2009; Ek and Söderholm, 2010; Gadenne et al. 2011; Thøgersen and Grønhøj, 2010; Zografakis et al., 2010; Martinsson et al., 2011; Wang et al., 2011; Yue, et al., 2013), perceived behavioural control variables (Ajzen, 1991), such as the (in)convenience to households when engaging in particular electricity-saving behaviours (Linderderg and Steg, 2007; Banfi and Farsi, 2008; Feng et al., 2010; Scarpa and Willis, 2010; Wang et al., 2011; Yue et al., 2013), and past experience variables (Ajzen, 1991; Feng et al., 2010; Zografakis et al., 2010), such as an electricity crisis, or the Wenchuan Earthquake of 2008. External incentives include supportive government policies, such as taxes and subsidies, or media promotion for environmental protection (Ueno et al., 2006; Bartiaux, 2008; Ek and Söderholm, 2010), and demand response variables, such as daylight saving time and information feedback about electricity usage, such as enhanced billing, time-of-use pricing, "electronic in-house display" and "smart meters" (Faruqui and George, 2005; Herter et al., 2007; Fischer, 2008; Faruqui, 2010; Herter and Wayland, 2010; Faruqui and Sergici, 2011; Newsham and Bowker, 2010; Stevenson and Rijal, 2010).

[2] Note: provinces located in Southern China are Fujian, Guangdong, Hunan, Hubei, Jiangsu, Sichuan, Yunnan, and Zhejiang, whereas those located in Northern China are Gansu, Hebei, Heilongjiang and Shaanxi.